# DECLARATION

I, Hiromi Hase, of SHIGA INTERNATIONAL PATENT OFFICE, OR Building, 23-3, Takadanobaba 3-chome, Shinjuku-ku, Tokyo, Japan, do hereby certify that I am conversant with the English and Japanese languages and am a competent translator thereof. I further certify that, to the best of my knowledge and belief, the attached English translation is a true and correct translation made by me of U.S. Provisional Patent Application No. 60/372,431 filed on April 16, 2002.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Signed the 15th day of April, 2003

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[Document Type] Specification

[Title of the Invention] METAL-COATED ABRASIVE, GRINDSTONE USING METAL-COATED ABRASIVE AND METHOD OF PRODUCING METAL-COATED ABRASIVE

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to an abrasive used in grinding wheels, coated abrasives, or the like and, more particularly, relates to a metal-coated abrasive wherein the surface of abrasive grains is coated with metal to enhance a retention force by which the abrasive is retained.

[0002]

[Prior Art]

A resinoid grinding wheel using a resin as a bonding material has problems in that abrasive often falls off during grinding, and the grinding ratio of the grinding wheel is reduced because it has a low retention force by which the abrasive is retained in a bond layer as compared with a grinding wheel using other types of bond. Therefore, various proposals to increase the retention force of the abrasive have been made.

[0003]

For example, there has been developed an abrasive whose surface is provided with single- or multi-layered coatings of nickel, nickel-phosphorus, cobalt, cobalt-phosphorus, titanium, copper, or the like, thereby improving retention force in a bond layer by means of irregularity of the coated surface, and the resulting abrasive is used in resinoid grinding wheels at present.

[0004]

Japanese Patent No. 1565561 discloses a method of producing a nickel-coated abrasive, which has irregularities on the surface and also has a high retention force, by providing a metal layer on the surface of abrasive grains and also providing a first layer made of a spongy nickel and a second layer made of a dense nickel.

[0005]

Also Japanese Patent Application, First Publication No. Hei 3-73426 discloses a resinoid grinding wheel whose grinding ratio was improved by providing a first layer made of nickel, a second layer made of cobalt, and a third layer made of nickel coating.

[0006]

As described above, the retention force by which the abrasive is retained in the bond can be increased by coating the surface of abrasive grains and, therefore, falling-off of the abrasive during grinding is reduced and the grinding ratio of the grinding wheel is improved.

[0007]

However, the retention force between the metal-coated abrasive and the resinoid bond is a physical retention force caused by irregularities of the coated surface. As the grain size of the abrasive to be used decreases, small irregularities are formed on the coated surface. Also as the grain size of the abrasive to be used decreases, the number of irregularities on the surface is reduced, and therefore, the contact area between the coated surface and the bond layer decreases, and the retention force by which the abrasive is retained in the resinoid bond becomes insufficient.

[0008]

In the grinding process, the grain size of the abrasive must be generally reduced to improve the surface roughness of a work material, and it has been strongly desired in the trend of size reduction and higher accuracy of workpieces in the industrial world to

develop an abrasive having a small grain size even when used in a resinoid grinding wheel. However, as described above, an abrasive having a small grain size still has a problem in that sufficient retention force is not attained even by surface coating, and also has problems, for example, of increased tool cost due to low grinding ratio, increase in total working cost due to increase in the number of trueing and dressing operations for adjustment of grinding wheel size and restoration of cutting edge, and impairment of surface roughness of a work material due to falling-off of abrasive grains.

[0009]

[Problems to be Solved by the Invention]

The present inventors have intensively researched to achieve the above objects. As a result, they have found a method which can yield a sufficient retention force on an abrasive in a resinoid grinding wheel even in the case of a small grain size and also can suppress the reduction of the grinding ratio, and thus the present invention has been completed. The present invention is directed to the following.

[0010]

(1) A metal-coated abrasive characterized in that plural abrasive grains, each coated by a metal layer, are bonded together.

[0011]

(2) The metal-coated abrasive according to (1), characterized in that the abrasive grains coated by the metal layer are bonded by a metal.

[0012]

(3) The metal-coated abrasive according to (1) or (2), characterized in that the abrasive grains coated by the metal layer are formed of plural grains.

[0013]

(4) The metal-coated abrasive according to any one of (1) to (3), characterized in

that the metal layer is formed of plural layers.

[0014]

(5) The metal-coated abrasive according to any one of (1) to (4), characterized in that the metal layer, with which the abrasive grains are coated, contains one selected from the group consisting of nickel, nickel-phosphorus, cobalt, cobalt-phosphorus, titanium, copper, chromium, iron, zirconium, niobium, molybdenum and tantalum.

[0015]

(6) The metal-coated abrasive according to any one of (1) to (5), characterized in that the metal layer is formed of a single layer of nickel or nickel-phosphorus.

[0016]

(7) The metal-coated abrasive according to any one of (1) to (5), characterized in that the metal layer is formed of two or more layers of which a first inner layer is formed of nickel or nickel-phosphorus and a second layer is formed of cobalt or cobalt-phosphorus.

[0017]

(8) The metal-coated abrasive according to any one of (1) to (5), characterized in that the metal layer is formed of three or more layers of which a first inner layer is formed of nickel or nickel-phosphorus, a second layer is formed of cobalt or cobalt-phosphorus, and an outermost layer is formed of nickel or nickel-phosphorus.

[0018]

(9) The metal-coated abrasive according to any one of (1) to (8), characterized in that the metal, by which the abrasive grains coated with the metal layer are bonded together, contains at least one metal selected from the group consisting of nickel, nickel-phosphorus, cobalt, cobalt-phosphorus, titanium, copper, chromium, iron, zirconium, niobium, molybdenum, and tantalum.

[0019]

(10) The metal-coated abrasive according to any one of (1) to (8), characterized in that the metal, by which the abrasive grains coated with the metal layer are bonded together, is nickel or nickel-phosphorus.

[0020]

(11) The metal-coated abrasive according to any one of (1) to (10), characterized in that the average grain size of the abrasive grains is within a range from 0.5 μm to 300 μm.

[0021]

(12) The metal-coated abrasive according to any one of (1) to (11), characterized in that the abrasive grains comprise at least one selected from the group consisting of cubic boron nitride, diamond, alumina, and silicon carbide.

[0022]

(13) The metal-coated abrasive according to any one of (1) to (12), characterized in that the abrasive grains comprise one of cubic boron nitride, diamond, and a mixture thereof.

[0023]

(14) The metal-coated abrasive according to any one of (1) to (13), characterized in that the average number of the abrasive grains bonded together is within a range from 2 to 100.

[0024]

(15) A grinding wheel using a metal-coated abrasive, characterized in that the metal-coated abrasive of any one of (1) to (14) is contained in an amount within a range from 5 % by weight to 100 % by weight.

[0025]

(16) A resinoid grinding wheel using a metal-coated abrasive, characterized in

that the metal-coated abrasive of any one of (1) to (14) is contained in an amount within a range from 5 % by weight to 100 % by weight.

[0026]

(17) A coated abrasive using the metal-coated abrasive of any one of (1) to (14).

[0027]

(18) A method of producing the metal-coated abrasive of any one of (1) to (14), characterized in that the metal layer coating the abrasive grains is formed by an electroplating or electroless plating method.

[0028]

(19) A method of producing the metal-coated abrasive of any one of (1) to (14), characterized in that the plural abrasive grains coated with the metal layer are bonded together by using an electroplating or electroless plating method.

[0029]

(20) A method of producing the metal-coated abrasive of any one of (1) to (14), characterized in that the metal coating layer is formed on the surface of the abrasive grains by dipping the abrasive grains in an electroplating or electroless plating bath while stirring, and then the abrasive grains coated with the metal layer are bonded together while gently stirring.

[0030]

[Means for Solving the Problem]

The metal-coated abrasive of the present invention is characterized in that plural abrasive grains coated with a metal are bonded together. In this case, the abrasive grains coated with a metal layer are preferably bonded by the metal, and the abrasive grains coated with the metal layer may be formed by plural abrasive grains.

[0031]

In Fig. 1 and Fig. 2, the metal-coated abrasive of the present invention is schematically shown. As shown in Fig. 1(a), the metal-coated abrasive of the present invention has a structure such that each of the abrasive grains 1 is coated with a metal layer 2 and the metal-coated abrasive grains are bonded by a metal 3. As shown in Fig. 1(b), the metal-coated abrasive of the present invention may have a structure such that plural abrasive grains 4 are coated with a metal layer 5 in the state of being bonded, and are bonded with other metal-coated abrasive grains 6 by a metal 7. In this case, the metal layer 2 and the bonding metal 3 may be made of the same or different kinds of metal. Also the metal layer 5 and the bonding metal 7 may be made of the same or different kinds of metal.

[0032]

Since the metal-coated abrasive of the present invention has such a structure, the retention force in the resinoid bond is increased, even when the size of the abrasive grains is small, and thus it is made possible to suppress falling-off of the abrasive during grinding and to remarkably improve the grinding ratio. As a result of the suppression of falling-off of the abrasive, the surface roughness is also improved.

[0033]

For example, a conventionally used cBN-coated abrasive is an abrasive obtained by coating a single abrasive grain with a single- or multi-layered metal such as nickel, nickel-phosphorus, cobalt, cobalt-phosphorus, titanium, copper, or the like, and is produced so that the resulting abrasive does not contain plural abrasive grains bonded by metal coating, like the metal-coated abrasive of the present invention. Therefore, as the grain size of abrasive grains decreases, the retention force between irregularities formed on the coated surface and the resinoid bond is reduced, and the cBN-coated abrasive often falls off during grinding, resulting in low grinding ratio which increases grinding cost.

[0034]

The abrasive grains used in the present invention may be made of either single crystal or polycrystal and also may be subjected to any surface treatment. The surface of the abrasive grains may be coated by ceramics or other metals in advance. As shown in Fig. 1(b), plural abrasive grains may be bonded together by sintering or other methods.

[0035]

The average grain size of the abrasive grains used in the metal-coated abrasive of the present invention is preferably within a range from 300 to 0.5 μm, and more preferably from 150 to 1 μm. When the average grain size exceeds 300 μm, bonding of the abrasive grains tends to exert a small effect. On the other hand, when the average grain size is less than 0.5 μm, it becomes difficult to control the degree of bonding of the abrasive grains in the case of providing the surface of the abrasive grains with a metal coating.

[0036]

The number of the abrasive grains to be bonded together in the metal-coated abrasive of the present invention is preferably within a range from 2 to 100, and more preferably from 2 to 50. When more than 100 abrasive grains are bonded together, the resulting metal-coated abrasive tends to be too large and distribution of the metal-coated abrasives in the resinoid grinding wheel tends to become non-uniform, and thus the quantity of abrasion at the abrasive-free portion tends to increase during grinding and the grinding ratio tends to be reduced.

[0037]

The content of the metal-coated abrasive of the present invention in the grinding wheel is within a range preferably from 5% by weight to 100% by weight, and more preferably 25% by weight to 100% by weight. When the content of the metal-coated abrasive is less than 5% by weight, sufficient effect of the use of the metal-coated abrasive

of the present invention is not exerted and the grinding ratio is hardly improved.

[0038]

The metal layer coating the abrasive grains preferably contains one metal selected from the group consisting of nickel, nickel-phosphorus, cobalt, cobalt-phosphorus, titanium, copper, chromium, iron, zirconium, niobium, molybdenum and tantalum. In the case in which the metal layer is composed of a single layer, it is preferably formed of nickel or nickel-phosphorus. In the case in which the metal layer is composed of two or more layers, the outermost metal layer is preferably formed of nickel or nickel-phosphorus. In the case in which the metal-coated abrasive grains are not completely coated with the metal layer, with which the abrasive grains are bonded, the outermost metal layer is preferably formed of nickel or nickel-phosphorus. Because nickel and nickel-phosphorus have good corrosion resistance, they are preferably selected for forming the outermost metal layer. In the case in which two or more metal layers are formed, inner metal layers are preferably formed of cobalt or cobalt-phosphorus. Since cobalt and cobalt-phosphorus have large resistance to deformation at high temperature and suppress deterioration due to grinding heat, they can protect the abrasive grains by preventing the abrasive grains from falling off and achieve the effect of improving the grinding ratio.

[0039]

In the metal-coated abrasive of the present invention, the metal, by which the metal-coated abrasive grains are bonded together, preferably contains one metal selected from the group consisting of nickel, nickel-phosphorus, cobalt, cobalt-phosphorus, titanium, copper, chromium, iron, zirconium, niobium, molybdenum, and tantalum. Among these metals, nickel or nickel-phosphorus is preferably used in view of corrosion resistance and productivity. The metal may be the same kind as that used in the metal layer.

[0040]

Examples of the abrasive grains used in the metal-coated abrasive of the present invention include cubic boron nitride, diamond, alumina, silicon carbide, and other powdered hard substances. These hard substances may be used alone or in combination. When using cubic boron nitride, diamond, or a mixture thereof as abrasive grains, particularly remarkable effects can be obtained. Since cubic boron nitride and diamond are excellent in abrasive grain strength but have relatively insufficient retention force by which the abrasive grains are retained in the bond, the effect obtained by the metal coating of the present invention is larger than that of the other hard substances and a remarkable effect can be obtained.

[0041]

In the formation of the metal layer of the metal-coated abrasive grain of the present invention, known methods such as an electroplating method, an electroless (chemical) plating method, a powder granulation method, a chemical evaporation method, a physical evaporation method, or the like can be used. Among these methods, an electroplating method is preferably used, in view of the productivity.

[0042]

The method of coating the metal layer on the abrasive grains according to the present invention will now be described using the case where nickel coating (nickel-phosphorus coating) is conducted by an electroless (chemical) plating method.

[0043]

Before conducting the nickel-phosphorus coating on the surface of the abrasive grains, a metal (for example, palladium) serving as a nucleus for deposition of nickel is preferably deposited on the surface of the abrasive grains. For example, the method of depositing a palladium metal (activation treatment) after dispersing and applying tin

chloride on the surface of the abrasive grains (sensitization treatment) is commonly used, and can be conducted in a known manner.

[0044]

Then, the abrasive grains are subjected to electroless plating wherein nickel-phosphorus is deposited on the surface of the abrasive grains by dipping in an electroless plating bath (for example, a mixed bath of nickel sulfate, sodium hypophosphite, sodium acetate, sodium citrate and sulfuric acid). In this case, the electroless plating bath is mixed with vigorous stirring so that the abrasive grains are not bonded by a metal to be plated. Since this state varies depending on the size and shape of the plating bath and the size and shape of the stirring blade, conditions must be set for each apparatus.

[0045]

In the stage where a nickel coating is formed on the surface of abrasive grains, stirring is performed slowly by reducing the revolution rate of the stirring blade, and thereby the abrasive grains are bonded. In that case, the degree of bonding is controlled by the rate at which stirring is slowed and the retention time.

[0046]

After the completion of metal coating, the metal-coated abrasive is taken out from the plating bath, washed with water, dried and then shifted through a sieve to obtain a metal-coated abrasive having a predetermined size of the present invention.

[0047]

In the case in which the resinoid grinding wheel is produced by using the metal-coated abrasive of the present invention, a higher grinding ratio is obtained as compared with the case of using a conventional metal-coated abrasive, and thus grinding cost is reduced. In the case of the resinoid grinding wheel using the metal-coated abrasive comprising abrasive grains having a very small grain size, a remarkable effect is exerted.

[0048]

As the bond of the resinoid grinding wheel of the present invention, a commercially available resinoid bond can be used according to the application field. Examples of the bond include bonds made mainly of a phenolic polymer compound and a polyimide-type polymer compound. The amount of the bond in the grinding wheel is preferably controlled within a range from 25% by volume to 90% by volume. When the amount of the bond is less than 25% by volume, the retention force by which the abrasive is retained is reduced and, as a result, the abrasive often falls off as the grinding ratio is reduced. On the other hand, when the amount of the bond is more than 90% by volume, the amount of the abrasive grains is reduced and, therefore, the resulting abrasive is not suitable for use in a grinding tool.

[0049]

In the resinoid grinding wheel of the present invention, additives can also be used which are commonly used in the production of the resinoid grinding wheels, such as solid antifriction agents, auxiliary bonding materials, aggregates, and porous materials.

[0050]

[Examples]

The following Examples illustrate the present invention in detail, but are not intended to limit the present invention.

[0051]

(Example 1)

1 kg of cBN abrasive grains SBN-B, manufactured by SHOWA DENKO K.K. (nominal grain size: G-30, average grain size: 22 μm) was subjected to a sensitization treatment and an activation treatment. Specifically, the abrasive grains were dipped in 1 liter of an aqueous tin chloride solution prepared by adding distilled water to 1 g of tin

chloride and 10 ml of hydrochloric acid, subjected to the sensitization treatment while being held and stirred at room temperature for 2 minutes, removed from the aqueous solution, and then slightly washed with water. Thereafter, the abrasive grains were dipped in 1 liter of an aqueous palladium chloride solution prepared by adding distilled water to 0.5 g of palladium chloride and 75 ml of hydrochloric acid, subjected to activation treatment while maintaining with stirring at room temperature for 2 minutes, taken out from the aqueous solution and then slightly washed with water.

[0052]

The abrasive grains subjected to the sensitization treatment and the activation treatment were dipped in 25 liters of a plating bath prepared according to the formulation shown in Table 1. After adjusting the pH to 5 using sulfuric acid, the plating bath was heated to 90°C and stirred at 60 rpm using a stirrer. For the plating bath, an aqueous sodium hypophosphite solution (5 mol/liter) was used until the plating bath became transparent, and then the abrasive grains were subjected to nickel-phosphorus coating. The main composition of the nickel-phosphorus layer was $Ni_3P$.

[0053]

After the plating bath became transparent, the revolution rate of the stirrer was decreased to 45 rpm and 25 liters of a plating bath (the pH was adjusted to 5 using sulfuric acid and was heated to 90°C) prepared according to the formulation shown in Table 1 was additionally charged. In the plating bath, an aqueous sodium hypophosphite solution (5 mol/liter) was added until the plating bath became transparent, and then nickel-phosphorus coating was conducted.

[0054]

After the plating bath became transparent, the nickel-phosphorus coated abrasive grains (metal-coated abrasive) were taken out from the plating bath, washed with water,

dried and sifted through a sieve having an opening size of 50 μm, and then a metal-coated abrasive on the sieve was observed using SEM. The SEM photograph is shown in Fig. 2.

[0055]

A portion of the metal-coated abrasive was removed and the metal coating was dissolved using an acid, and then a weight ratio of the metal layer was calculated. As a result, it was 60.4% by weight.

[0056]

(Comparative Example 1)

Under the same conditions as in Example 1, 1 kg of cBN abrasive grains SBN-B, manufactured by SHOWA DENKO K.K. (nominal grain size: G-30, average grain size: 22 μm) were subjected to a sensitization treatment and an activation treatment, and were then dipped in 50 liters of a plating bath prepared according to the formulation shown in Table 1. After adjusting the pH to 5 using sulfuric acid, the plating bath was heated to 90°C and stirred at 60 rpm using a stirrer. In the plating bath, an aqueous sodium hypophosphite solution (5 mol/liter) was added until the plating bath became transparent, and thereby the abrasive grains were subjected to nickel coating using an electroless plating method.

[0057]

After the plating bath became transparent, the nickel-phosphorus coated abrasive grains (metal-coated abrasive) was taken out from the plating bath, was washed with water, was dried, and then was observed using SEM. The SEM photograph is shown in Fig.3.

[0058]

A portion of the metal-coated abrasive was removed and the metal coating was dissolved using an acid, and then a weight ratio of the metal layer was calculated. As a result, it was 60.4% by weight.

[0059]

(Example 2 and Comparative Example 2)

Using the abrasive grains produced in Example 1 and Comparative Example 1, resinoid grinding wheels were produced.

[0060]

The shape and formulation of the resulting grinding wheels are shown below. The shape of the grinding wheel is represented by the symbol defined in JIS B 4131 (diamond and cubic boron nitride wheel), while the symbol 1A1 denotes the shape of the grinding wheel, symbols D, U, X and H respectively denote outer diameter of the grinding wheel, width of the grinding wheel (abrasive grains layer), thickness of abrasive grain layer, and hole diameter of the attaching portion, and the unit is mm.

[0061]

Shape of grinding wheel:

1A1 shape: 150D × 5U × 3X × 76.2H

Formulation:

Metal-coated abrasive: 30.6% by volume

Resinoid bond: 69.4% by volume (phenol resin)

[0062]

(Example 3 and Comparative Example 3)

With respect to resinoid grinding wheels obtained in Example 2 and Comparative Example 2, a grinding test was conducted under the following conditions. The results of the grinding test are shown in Table 2.

[0063]

Grinding machine: horizontal spindle surface grinding machine (axial motor of grinding wheel: 3.7 kW)

Work material: SKH-51 (HRc = 62 to 64)

Surface of work material: 200 mm × 100 mm

Grinding system: wet surface traverse grinding system

Grinding conditions: Peripheral speed of grinding wheel: 1500 m/min

Table speed: 15 m/min

Cross feed: 2 mm/pass

Depth of cut: 2 μm

Grinding fluid: JIS W2 soluble type, exclusive fluid for cBN

[0064]

[Table 1] Formulation of nickel plating bath

| | |
|---|---|
| Water | 50 liter |
| Nickel sulfate | 25 mol |
| Sodium acetate | 75 mol |
| Sodium citrate | 10 mol |

[0065]

[Table 2] Results of grinding test

| | Grinding ratio | Value of grinding power (W) | Surface roughness Ra (μm) |
|---|---|---|---|
| Example 3 | 523 | 225 | 0.05 |
| Comparative Example 3 | 305 | 230 | 0.09 |

[0066]

[Effects of the Invention]

Since the metal-coated abrasive according to the present invention is an abrasive in which plural abrasive grains are bonded together by metal coating and which has a higher retention force in a resinoid bond than that of a conventional metal-coated abrasive, falling-off of the abrasive is reduced, and therefore, it becomes possible to produce a resinoid grinding wheel, which can achieve a higher grinding ratio. As a result of the suppression of the falling-off of the abrasive during grinding, the surface roughness of a work material is improved.

[Brief Description of the Drawings]

[Fig.1] A schematic view showing the metal-coated abrasive according to the present invention.

[Fig.2] A SEM photograph of the metal-coated abrasive according to the present invention.

[Fig.3] A SEM photograph of the metal-coated abrasive according to the prior art.

[Brief Description of the Reference Symbols]

| | |
|---|---|
| 1 | abrasive grain |
| 2 | metal layer |
| 3 | metal |
| 4 | abrasive grain |
| 5 | metal layer |
| 6 | metal-coated abrasive grain |
| 7 | bonding metal |

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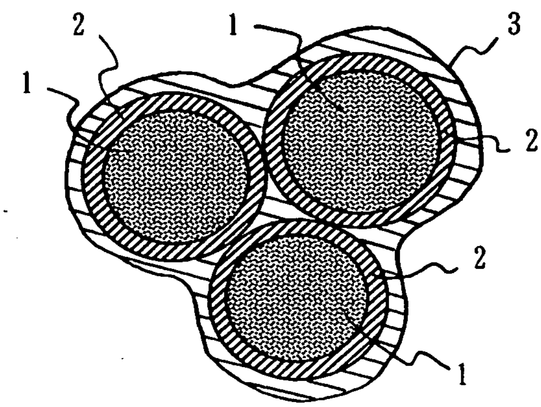
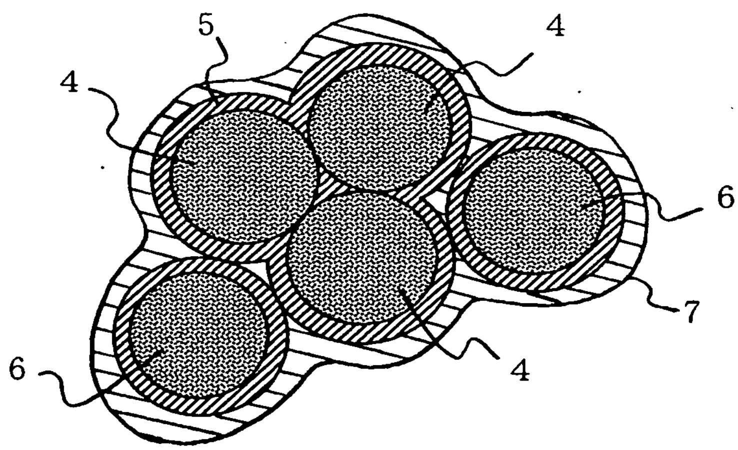
[Fig. 1]




(a)




(b)

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[Fig. 2]

[Fig. 3]